

2.3 Understanding Exposure



Congratulations, you've landed a great summer job! Not only will you be able to work outside, you might even get the opportunity to play lots of golf as well. Maintaining the condition of the fairways, greens, and other parts of a golf course is a complex job that requires the superintendent and crew to utilize a variety of chemical substances, including fertilizers, herbicides, insecticides, and pesticides. As part of the grounds crew, you will be required to handle and use many of these substances. Which substance should you be concerned about the most? What actions can you take to reduce your concerns?

In this lesson you will learn more about some of the substances that are present in your environment. Considering that you spend a great deal of time both indoors and outdoors, the choices you make about the substances you use in your daily activities and how you handle them influence what you will be exposed to.

Painting is probably one of the many tasks you will be asked to complete, whether at home or while on the job. Imagine you were given permission to decorate your room in any style you choose. Think of all the choices!

Renovating a room, an apartment, or a house involves many decisions. Not only are there colours to consider, there are so many different materials from which to choose. The smell of fresh paint is very distinct; it is also an indication of the presence of volatile organic compounds (VOCs) released by the paint through a process called **off-gassing**. Flooring, along with other materials used in decorating, can release VOCs through off-gassing as well. Because of the amount of time people spend inside, **indoor air quality** and exposure to VOCs from off-gassing is a concern for many people.



- ▶ **off-gassing:** the release of volatile organic compounds from building materials
- ▶ **indoor air quality:** an evaluation of the air within a room or structure

Science Links

In addition to VOCs, the air inside a room may contain mould, carbon monoxide, ozone, and even pesticides. People with asthma and allergies are especially sensitive to the air quality and substances present. Dust, mould, and insects in a room can trigger allergic reactions. To prevent the accumulation of allergens, smooth, washable surfaces are recommended along with frequent cleaning of floors, walls, and shelves. Have you included information about any substances you are allergic to or perhaps that you have asthma in your personal health file you started in Unit A?



Concerns Regarding Off-Gassing

One way to prevent off-gassing is to use products that do not contain volatile organic compounds (VOCs). Paint and related products that do not contain VOCs—like ethan-1,2-diol (ethylene glycol) or 1,2-dichloroethane (a halogenated hydrocarbon)—are available from many manufacturers.

As paints or solvents dry, the compounds identified as VOCs evaporate and mix into the air in the room, where it can be inhaled. People who spend many hours indoors—in hospitals, day-care facilities, and schools—tend to have a higher level of exposure to VOCs. Reduced-odour paint provides one alternative that reduces exposure. People who work or live in newly-painted rooms experience only a short-term exposure. On the other hand, painters, who work with paint daily, experience long-term exposure. In addition to carefully choosing paint, simple practices like wearing gloves and clothing to protect skin from direct contact can also help reduce exposure.



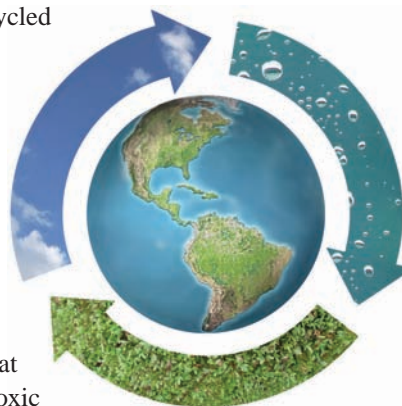
Figure B2.22: Odourless paint and paint supplies do not contain VOCs.

Building Materials Can Limit Environmental Impact



Figure B2.23: Labels often provide instructions on how to access additional information about a product, including its effect on indoor air quality.

In addition to paint, other building materials like lumber, flooring, and floor and wall covering materials can be manufactured from recycled materials or from materials developed that use alternative technologies. Labels can indicate that a product has met national standards. When buying building materials and other products that are environmentally friendly, you are supporting companies that use processes that reduce the amount of material sent to landfills and use alternatives to toxic chemicals. Because of your decision, you may find yourself walking on a carpet containing plastic recycled from pop bottles, hanging a picture on a wall built from wood produced by a quick-growing variety of tree that absorbs carbon dioxide from the atmosphere at a high rate, or using wood that was not treated with toxic substances. Information about most building products is available on the Internet or at stores that stock the product.



In the next activity you will consider materials you could use for redecorating your room.

Practice

25. Draw the chemical structure of the VOC 1,2-dichloroethane. Identify one environmental concern associated with halogenated hydrocarbons.
26. Explain how removing halogenated hydrocarbons from paint could address the environmental problem identified in question 25.

Science Links

Safety gear, like protective suits, gloves, and masks to filter inhaled air, prevents exposure to chemicals used in automobile paint. Short- or long-term exposure to certain substances may affect the body. Similarities exist between exposure to radiation and to certain chemicals. For more information about sources of radiation you may be exposed to, go to Unit C.



Utilizing Technology

Risk-Benefit Analysis of Renovation Materials

Background Information

In this activity you will plan a renovation for a room in your home. A risk-benefit analysis involves considering many factors before you start the project. You will conduct research on some options that exist for the materials you plan to use to complete the renovation. You will also evaluate your renovation plan by considering technological, ecological, and economic factors.

Purpose

You will investigate and evaluate the use of products that decrease the release of synthetic organic compounds into the environment.

Procedure

- step 1:** Sketch the room you intend to renovate. In your sketch, include measurements of the dimensions of the room as well as the number and size of windows and doors.
- step 2:** List the materials required to complete the renovation you proposed. You may wish to use a spreadsheet to organize the information you collect in the steps that follow. Consult your teacher as to how extensive your renovation plan can be (e.g., paint, draperies, flooring, and mouldings).
- step 3:** Use the room measurements and, if necessary, the Internet to research information about the amount of each material listed in step 2. For example, some websites can estimate the amount of paint required. Record the amount of each material required in your spreadsheet.



Science Skills

- ✓ Performing and Recording
- ✓ Analyzing and Interpreting

- step 4:** Use the Internet to research an environmentally friendly paint or an alternative to painting. Identify characteristics that enable these products to be designated as “environmentally friendly.”
- step 5:** Visit some local businesses that sell the materials you need to complete your plan. Identify the products you would like to use. List the technological, economic, and ecological aspects of the product in your spreadsheet. These aspects may include ingredients or substances used in its construction, durability, performance, texture, look, limitations, and cost.
- step 6:** Collect information about environmentally friendly alternatives to the products you have chosen in step 5. Collect information about the environmentally friendly products for your spreadsheet that will allow for a comparison. Use the information in your spreadsheet to compare the products.



Analysis

1. Calculate the cost for completing the renovation project using environmentally friendly materials and the other alternative products.
2. Compare the environmentally friendly materials with the other alternative products in terms of technological, economic, and ecological factors.
3. Finalize your renovation plan, and list the products you would use. Defend your choices.

Targeting Toxic Chemicals



pesticide: a substance used to kill fungi, insects, animals, or plants considered as pests

Choices about products other than paint can influence which chemicals you are exposed to. In Lesson 2.2 you evaluated the use of vinegar as a cleaning product. Are there other substances you are exposed to?

At a golf course, or possibly at home, one or more forms of **pesticide** are used. The term *pesticide* is a very general one, since so many different types of pests exist. The “Pesticides” table lists some of the pesticides used by homeowners.

PESTICIDES

Type	Purpose	Types of Organic Compounds
insecticide	to remove insects that may cause damage or disease in domestic locations, agriculture, and forestry	halogenated hydrocarbons and various organic compounds
herbicide	to remove unwanted plants that compete for nutrients and sunlight, affecting the growth of desired plants	various organic compounds
fungicide	to protect crop plants and animals from fungi that can cause disease; can also be used to prevent the growth of moulds in food or within homes	phenols



DID YOU KNOW?

Other types of pesticides commonly used include acaricides (kill mites and ticks), rodenticides (kill small mammals like mice and gophers), algicides (kill algae in ponds or swimming pools), and disinfectants (kill micro-organisms).

Utilizing Technology

Constructing a Database of Pesticides Used in the Home

Purpose

You will prepare a database of pesticides used around your home.

Procedure

Search your home, garage, or other buildings for household and garden products used to remove pests. Prepare a database of the products you find. Include the following information about each product in your database:

- product name
- intended use
- type of pesticide (herbicide, insecticide, etc.)
- name of ingredient used as killing agent in product

Check your database by searching for a name of a compound within it or by sorting the information alphabetically by product name.

Analysis

1. Identify a purpose for the database of pesticides in your home.
2. Identify additional information you would add to the database along with a justification.



Science Skills

✓ Communication and Teamwork



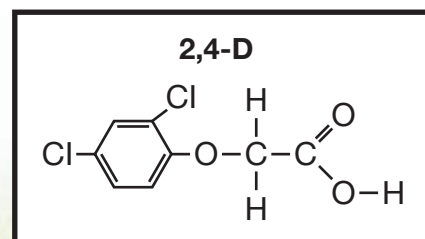
Considerations When Using Pesticides—Specificity

Chemical technologies, like pesticides, act as tools to achieve a desired purpose. On a golf course, farm, or in your yard or garden, herbicides may be used to control the growth of weeds. Careful selection of a substance that is appropriate for a pest involves knowing the pesticide's **target specificity**.

When the correct tool is selected for a job, there is a better chance of success. As you may have noticed from the database you constructed in the preceding activity, you probably have a variety of products in your home, each designed to control a specific type of pest. Some pesticides have high target specificity and are designed to act on a small range or even just one type of insect or plant. A **broad-spectrum pesticide** is a product that has low target specificity and will act more generally, affecting many species. Can you identify the pesticides in your database that have high target specificities? Can you identify those that can act on a broad spectrum?

An example of a highly selective herbicide is 2,4-D, which is short for (2,4-dichlorophenoxyethanoic acid). This herbicide is one of the more popular herbicides used in Alberta. Similarities between the chemical structure of 2,4-D and hormones that control the growth of the plant allow the herbicide to be taken to the stem and root tips, where it interferes with the plant's growth. Dandelions, clover, thistle, and other broad-leaved plants are most affected by 2,4-D, whereas narrow-leaved grasses and crop plants (e.g., wheat) are less affected.

Prior to using a pesticide, it is important to consult information about the **toxicity** of the product. This information may not always be available on the product label, but it can be obtained using the Internet or from the site of purchase.



- ▶ **target specificity:** the range of organism(s) affected by a pesticide
- ▶ **broad-spectrum pesticide:** a chemical substance that can control the population of a large variety of organisms
- ▶ **toxicity:** the ability of a substance to cause damage to living tissue, impair the function of a body system, or cause death when ingested, inhaled, or absorbed through the skin

LD₅₀ and LC₅₀

Tests to determine toxicity of a pesticide focus on more than the target species. The most common ways to express information about the toxicity are LD₅₀ and LC₅₀. These values state concentrations at which a significant killing effect on an organism is observed. LD₅₀ values are often expressed in milligrams of chemical substance per kilogram of animal tested. A substance with an LD₅₀ value below 43 mg/kg is considered to be highly toxic. Since pesticides often end up in bodies of water (lakes, pools, etc.), LC₅₀ is often used to express the concentrations at which toxic effects on aquatic organisms occur. Products with low LD₅₀ values for the target organism are popular choices for use in pest control because, in theory, smaller amounts of pesticide will be required to control the pests. Broad-spectrum pesticides should also have low LD₅₀ values, but this will often be for a variety of pests.

- ▶ **LD₅₀**: the dosage of a chemical substance, given all at once, that kills half (50%) the population tested within a specified time
- ▶ **LC₅₀**: the concentration of a chemical substance in air or water that kills half (50%) the population tested within a specified time

Regardless of target specificity, pesticides should not affect non-target organisms. When looking at toxicity data, you may note that LD₅₀ values are stated for many non-target organisms, often at different stages in their lifecycle. Prior to licensing a product, the Government of Canada requires that sufficient testing be completed to ensure that a pesticide will have minimal impact on non-target organisms at various levels in the food chain. It is important to note LD₅₀ values for mammals that are tested because this data may provide information about what concentrations may be toxic to humans.

Practice

27. Describe an advantage and disadvantage of using the following.
 - a. a pesticide that can kill only one type of insect
 - b. a pesticide that can kill many types of insects
28. Scientists testing 2,4-D and an ester of 2,4-D compared LC₅₀ values.

LC₅₀ VALUES FOR 2,4-D AND 2,4-D ESTER

Organism		LC ₅₀	
		2,4-D	2,4-D Ester
chinook salmon	3 months to 1 year old	1.250 mg/L	0.246 mg/L
rainbow trout	3 to 5 days old	0.642 mg/L	0.329 mg/L
	3 months to 1 year old	1.555 mg/L	0.342 mg/L

- a. Use the information in the table to identify the substance that has the greater toxicity.
 - b. State reasons why experiments are performed to determine the LD₅₀ and LC₅₀ values for a variety of organisms.
 - c. Use a structural diagram of 2,4-D to indicate how it could be modified into an ester.
29. Explain whether LD₅₀ and LC₅₀ test the effects of short-term or long-term exposure to a substance.

SOME LD₅₀ AND LC₅₀ DATA FOR 2,4-D

Organism	LD ₅₀ or LC ₅₀
<i>Daphnia</i> (aquatic invertebrate)	25 mg/L
rainbow trout	358 mg/L
frog	359 mg/L
earthworm	350 mg/kg soil
quail	668 mg/kg
mallard duck	2000 mg/kg
mouse	370 mg/kg
rat	375–666 mg/kg



DID YOU KNOW?

Estimates on the financial impact of pesticide use suggest that for every dollar spent on pesticides, there is a return of \$4 due to greater productivity.



Considerations When Using Pesticides—Combined Effects

When looking at the labels of pesticides found in your home, you may have noticed that the products are often a mixture of compounds and may include trace amounts of by-products. Toxicity data is not routinely collected for commercial products; therefore, there are concerns regarding the effects that combinations of organic compounds used in pesticides may have on the environment and on humans.

Studies testing the toxicity of commercial pesticides suggest that surfactants and other compounds in the products alter the level of toxicity.



DID YOU KNOW?

Absorption of some pesticides through the skin is higher when sunscreens are worn. Despite this information, the use of sunscreens is encouraged.

Considerations When Using Pesticides—Drift, Grasshopper Effect, and Persistence

Spraying is one way to ensure direct contact between the pest and the pesticide; but weather and even the properties of the pesticide can affect contact. Spraying on a windy day can cause herbicides or insecticides to **drift** onto neighbouring crops or bodies of water. As you discovered earlier in this unit, the solubility of organic compounds in water can result in aquatic invertebrates, amphibians, fish, and other species in these ecosystems becoming exposed to the pesticide. Also, a rainfall after spraying may result in pesticides being transported into the soil with rainwater or into bodies of water in runoff.

The volatility of many organic compounds may result in pesticides travelling in wind currents from the site where they were applied. Pesticides detected in the Arctic are believed to have been transported by the **grasshopper effect**.

Modifications, such as synthesizing esters of 2,4-D, change the volatility of a compound and the performance of the pesticide. As you might predict after completing the “Making Esters” investigation in Lesson 2.2, an ester of 2,4-D would have an increased volatility and a greater tendency to drift or be transported larger distances by the grasshopper effect if used in very warm climates.

Pesticides containing halogenated hydrocarbons and organic compounds containing benzene rings often demonstrate **persistence** in the environment. Soil micro-organisms can act on pesticide molecules—using them as a source of carbon for their own growth—resulting in low persistence. Without the action of soil micro-organisms or chemical reactions that occur by exposure to sunlight, the molecules remain unchanged. Pesticides are designed to be applied at specific times during a growing season to co-ordinate with the life cycle of insects, the germination time of seeds, or the times of rapid growth in plants. Problems occur when pesticides remain in the air, soil, or water or when they are present in the tissues of other organisms in an ecosystem. As you saw with the heavy metal mercury and the persistent pesticide DDT, biomagnification results in toxic effects appearing in organisms higher up the food chain. Given the position of humans in the food chain, prolonged exposure to pesticides containing persistent organic compounds, even at low levels, may have negative health effects over a lifetime.

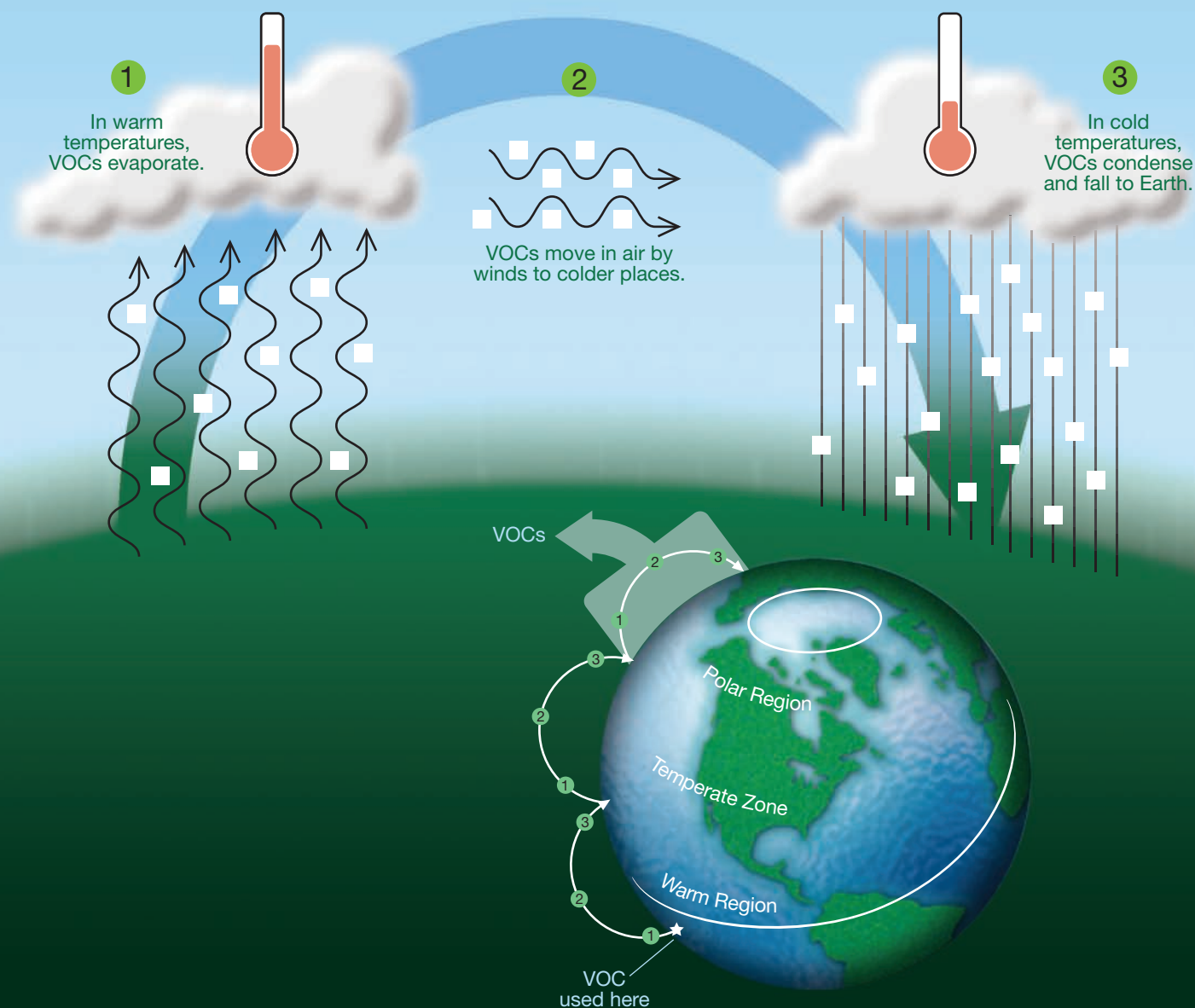
- ▶ **drift:** the transfer of a pesticide by wind or air currents from the location where it is sprayed
- ▶ **grasshopper effect:** the transport of pesticides that results from their evaporation in warmer climates and condensation and deposition in colder climates
- ▶ **persistence:** the resistance of a chemical substance being broken down by biological or chemical means



DID YOU KNOW?

Inhalation is a major route by which pesticides can enter your body. Directions for use for many pesticide products suggest that the area be avoided immediately after spraying to allow the substance to settle.

The Grasshopper Effect



Considerations When Using Pesticides—Water Quality

Try This Activity

Hypothesizing Patterns for Water Quality

Background Information

Tests performed on water samples include the detection of organic compounds. Assume you are working for Alberta Environment and plan to conduct a study that monitors the frequency at which different pesticide compounds are found in surface waters throughout the province. Surface water may be located in a variety of forms:

- lakes
- rivers
- creeks
- wetlands
- irrigation canals and drains
- urban creeks

Purpose

You will formulate a hypothesis about pesticide use over a year in Alberta and describe how such a study can be conducted.

Questions

1. Prepare a table that lists the forms of surface water from which you collect water samples. In the table, indicate whether the pesticides originate from agricultural, industrial, and/or domestic use.
2. Obtain the handout “Predicting Pesticide Use” from the Science 30 Textbook CD. Sketch a line that describes the expected trend for pesticide concentration in all water samples collected each month during a one-year study. Provide an explanation for the pattern, including any peaks or troughs that may be shown.
3. Sketch a second line that identifies the expected trend for the number of different pesticides that would be detected each month during a one-year study. Provide an explanation for the pattern, including any peaks or troughs that may be shown.



Science Skills

- ✓ Initiating and Planning



Figure B2.24: A location on the Bow River in winter and summer.

Fertilizers and Organic Matter—Effect on Water Quality

In parts of this unit you studied the effects on water quality of acid deposition and persistent organic compounds. The leaching of metal ions and persistent organic compounds used as pesticides are not the only substances that can affect the quality of surface water sources. Contaminating bodies of water with **fertilizers** or **organic matter** can also negatively impact aquatic ecosystems.

- ▶ **fertilizer:** a substance containing one or more nutrients required by plants
- ▶ **organic matter:** waste or decaying material from plants or animals



Figure B2.25: Tests are conducted to determine water quality.



Have you ever had a day at a lake affected by the presence of a thick layer of algae growing over its surface? An **algal bloom** can be a common occurrence in many prairie lakes. Rapid growth of algae is the result of high nutrient content in the lake's water. Many prairie lakes are considered to be **eutrophic**. They can be considered examples of well-developed ecosystems in which a rapid conversion of nutrients occurs.

Domestic and agricultural fertilizers commonly contain nitrogen and phosphorous—essential plant nutrients. As stated earlier, leaching is a common mechanism for removing substances that were sprayed onto a crop.



Figure B2.26: Irrigation canal amid fields of crops

The leaching of fertilizers and organic matter rich in nitrogen and phosphorous from fields into surface water adds additional nutrients. A rapid growth of algae and other plants is a natural response to this abundance of nutrients.

Toxins produced by species of blue-green algae that are present within an algal bloom can affect the health of humans and livestock. Symptoms of exposure to these toxins include skin irritation, rashes, sore eyes, swollen lips, and allergic reactions similar to hay fever. In some cases, severe illness and death of livestock has occurred from the consumption of water containing these toxins.

The decomposition of algae from an algal bloom can produce a dramatic change to the quantity of oxygen dissolved within a body of water. During winter months, the layer of ice over the surface prevents the absorption of oxygen from the atmosphere. Many processes occurring within the lake require oxygen. In addition to the oxygen needed for the respiration of fish and other organisms, oxygen is required for the decomposition of organic matter. In the winter following an algal bloom, additional oxygen is used by micro-organisms involved in the decomposition process. **Winterkill** occurs when the concentration of dissolved oxygen falls below the levels necessary to support fish species within the lake.

A **biochemical (biological) oxygen demand (BOD)** test is a measure of the effects of organic matter and other substances present within a water sample will have on dissolved-oxygen concentration. This test consists of comparing the dissolved-oxygen concentrations of a sealed water sample at the beginning and end of the test period (often five days). A decrease in the concentration of dissolved oxygen within the sample occurs when micro-organisms decompose organic matter. Water samples containing higher levels of organic matter (high BOD) tend to demonstrate a large reduction in dissolved-oxygen concentration.

Water contaminated by organic matter from human or animal waste may have a high BOD or may serve as a source of nitrogen and phosphorous that promote algal blooms. Despite these possibilities, the greatest concern regarding the release of **sewage** directly into water systems is the possible exposure to disease-causing viruses and bacteria. The World Health Organization estimates that water-borne diseases are the leading cause of death in the world. Contaminated water containing a strain of the bacterium *E. coli* (*Escherichia coli*) produces a toxin that severely affects humans.

Higher nutrient levels and the presence of bacteria from human and animal waste in Alberta lakes and waterways have resulted in a greater concern about water quality. Individual homes, settlements, and municipalities with insufficient water-treatment systems are required to boil their water before use to remove harmful bacteria. Some First Nations settlements in Alberta concerned about the use of chlorine as a disinfectant to treat water are investigating the use of chemical-free water-treatment systems.

- ▶ **algal bloom:** a rapid increase in the population of algae
- ▶ **eutrophic:** of a body of water having excessive plant growth due to a rich supply of nutrients
- ▶ **toxin:** a substance that can have harmful effects
- ▶ **winterkill:** the death of water organisms caused by the depletion of oxygen in an ice-covered body of water
- ▶ **biochemical (biological) oxygen demand (BOD):** a measure of the amount of oxygen required for the decomposition of organic matter
- ▶ **sewage:** waste matter often carried in sewers



DID YOU KNOW?

The deaths of seven people in Walkerton, Ontario, was caused by the ingestion of water contaminated with bacteria from cattle manure.

Practice

30. Use the following information to complete questions 30.a. and 30.b.

	Dissolved-Oxygen Concentration (mg/L)		
	Sample A	Sample B	Sample C
Start	10	9	5
End	8	2	2

- Use the values for dissolved oxygen to rank the water samples from lowest to highest with respect to BOD.
- Match each water sample with one of the possible sources listed in the table.

Possible Source	Sample
raw sewage	
river water upstream of major city	
river water downstream of major city	

Considerations When Using Pesticides—Resistance

Rodent pests, like gophers and prairie dogs, can cause considerable damage to a golf course. Some farmers are concerned about their farm animals getting injured by stepping in holes made by rodents. Many people, at some point or another, have worried about being exposed to a virus carried by mice (e.g., hantavirus). There are many reasons for people to use pesticides well beyond those associated with maintaining high crop productivity. However, this broad use of pesticides can result in the development of **resistant populations**.

resistant population: a group of organisms not affected by a pesticide

Recall from Unit A that genetic principles, including mutation, create variation within a population. Variation can result in some members of the population possessing resistance to a pesticide. After application, only resistant individuals remain in the population and are able to thrive as a result of reduced competition. Since genetic traits are inherited by offspring, the population of resistant organisms increases. You may also recall that breeding between resistant and non-resistant pest populations tends to result in offspring that are resistant, further reducing the effect of existing pesticides.

It may seem like a contradiction, but pest-management practices designed to kill higher percentages of the pest population often result in the fastest development of resistant pest populations.

Warfarin is a chemical compound that acts as an anticoagulant—preventing the action of platelets, which are responsible for the clotting of blood. Warfarin was first used in the 1950s to control rodent populations. Currently, warfarin and a variety of related compounds, called first-generation anticoagulants, are ineffective on many rodents because of the development of resistance to these chemical compounds. Effective rodent control in many situations now requires the use of second-generation anticoagulants.

The development of pesticide-resistant populations may be the result of poor pest-management practices, including relying too heavily on one product. By alternating the type of pesticide used or using alternative procedures, you increase the ability to control pests resistant to one pesticide.





Figure B2.27: Traps and pesticide-laden seeds are both effective methods of controlling mice.

Have you ever noticed signs of mice present in your garage or in your home? If so, you have a variety of choices. First, you need to determine whether they are a pest and whether they present any reason for concern. For some people, co-existing with mice presents no real problem. For others, minimizing contact may be a priority. A variety of alternatives to control mice exist, but which would you choose? If the problem is due to only a small number of mice, then trapping or the short-term use of a poison may be all that is required. Removing the pesticide once there are no further signs of mice reduces the risk of selecting individuals in the population that may be resistant and the risk of accidental exposure to pets. If the level of infestation is more severe or the mice do not seem to be affected by the methods you have used, a pest-control specialist may need to be consulted.

Practice

31. Explain how leaving pesticide-laden seeds or other poisons in traps for an extended period of time might increase the possibility of developing resistance to a pesticide within a population of pests.
32. Use the Internet to add information about the target specificity, LD_{50} , persistence, and development of resistance to the pesticides listed in the database you developed earlier in this lesson.



Chemical Inventory—Toxic Substances List

Earlier, you completed an activity and prepared a database of pesticides used in your home. Your database provides information about the substances used and other information, like safety and instructions for proper use. Lists like this are important resources for information about substances people are exposed to.

Federal, provincial, and municipal levels of government in Canada are involved in the management of chemical substances. These substances may be used in consumer products, by industry, or in the maintenance of parks and recreation areas. Currently, federal legislation restricts the use of more than 1000 chemical compounds, with an additional 23 000 compounds that have been assessed for their impact on humans and the environment.



DID YOU KNOW?

To view the Toxic Substances List and to see how dangerous substances have been classified, visit the following website:

http://www.ec.gc.ca/CEPAREgistry/subs_



Substances appearing on the Toxic Substances List have been organized using the following categories:

- Persistent Substances
- Bioaccumulative Substances
- Inherently Toxic to the Environment

Two additional categories in this database are used to identify health concerns for humans from exposure to substances. These categories are

- Greatest Potential for Exposure
 - indicates how often a substance is used and the possibility for exposure
- Inherently Toxic to Humans
 - substances known or suspected of having harmful effects on humans



DID YOU KNOW?

It is estimated that \$300 million will be required to complete the research needed to update the Toxic Substances List.

Practice

33. Evaluate the categories used in the Toxic Substances List by indicating both good and bad points about the categories.
34. DDT is a substance on the Toxic Substances List and is not permitted for use in Canada. Use the Internet to identify the evidence used to place DDT on the list. Use this evidence to determine under which categories DDT would appear.



Utilizing Technology

Updating Canada's Toxic Substances List—Debate

Chemical technologies often result in the production of new chemical compounds. Over time, additional information about exposure to and the environmental effects of existing substances can be collected and evaluated. An update to the Toxic Substances List would involve the use of funds collected from taxes to allow for the required testing of new and existing substances.



Science Skills

- ✓ Performing and Recording
- ✓ Analyzing and Interpreting

Question

Should government funds be spent to update Canada's Toxic Substances List?

Procedure

step 1: Read each of the following articles from the Science 30 textbook CD:

- *List of Toxic Chemicals Tests Tories on Environment*
- *Gov't Targets Toxic Chemicals*
- *Scientists Call for Tougher Rules on Toxic Chemicals*



step 2: Identify which stakeholders are represented by the information presented in the articles. Identify other stakeholders who may be affected by this issue. These may include other levels of government, industry, agriculture, or the public. Use the Internet to collect information that represents the position of the other stakeholders about this topic.



step 3: Choose a debate position—either for or against—to the question stated.

step 4: If necessary, conduct additional research the aspects or impact of the Toxic Substances List. Determine how this information could be used to support your position in a debate.

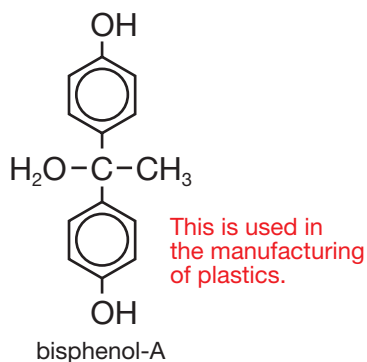
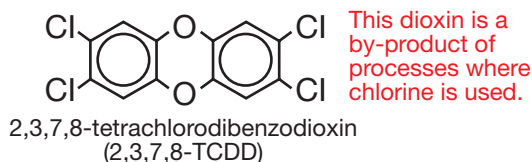
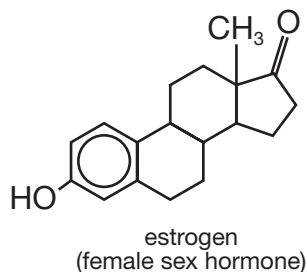
step 5: Use information collected during your research to state and defend your position in a debate on this issue.

Using Chemical Knowledge to Understand the Effect of Exposure

Substances can be added to the Toxic Substances List after they have been used in commercial products or chemical processes, provided that sufficient scientific evidence demonstrating harmful effects has been collected. Earlier in this unit you discovered that CFCs and benzene are examples of compounds that were restricted once evidence about their harmful effects on the environment and to humans had been demonstrated. Reasons for studying environmental chemistry include gaining a better understanding of chemical interactions in the environment and becoming better able to predict and prevent adverse effects from the chemical substances used by society.

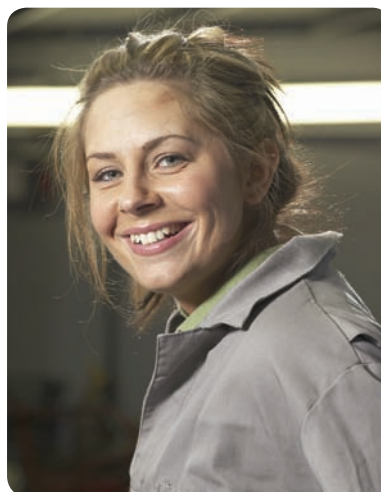
One way to predict possible environmental effects is to group substances by similarities in chemical structure. You have already learned that a common problem associated with halogenated hydrocarbons and synthetic organic compounds containing benzene rings is their persistence in the environment.

Estrogen and Estrogen-Mimicking Compounds



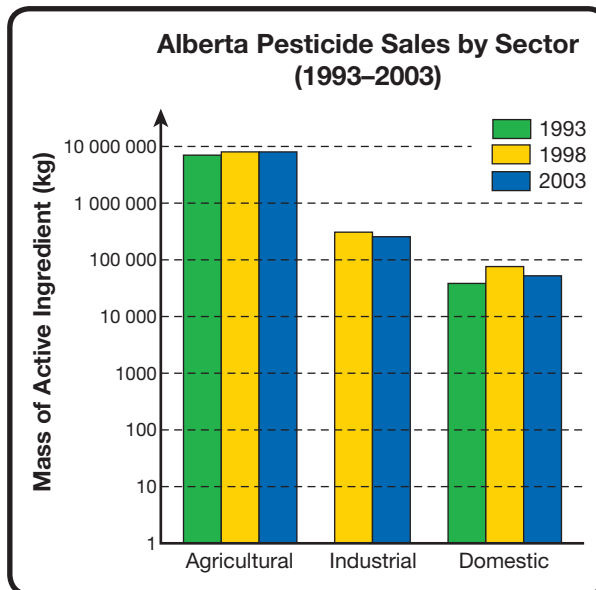
By-products of 2,4-D production can include chlorinated dioxin compounds. Although these compounds are found at levels that are barely detectable, chlorinated dioxins are associated with a number of adverse health effects in humans, such as decreased immune-system function, interference with hormonal systems, and linkages to some forms of cancer. Similarities between the chemical structure and shape of the female sex hormone estrogen and synthetic organic compounds, like dioxin, are believed to allow dioxins to stimulate cells in a manner similar to that of estrogen. Estrogen-mimicking compounds, like bisphenol-A (used in the manufacture of plastics), is suspected of influencing the development of sexual characteristics in males and females in various organisms. Synthetic organic compounds that influence the levels of sex hormones can effect reproductive cycles, fertility, and behaviour in a variety of organisms. These observations have increased interest focused on identifying and studying endocrine-disrupting compounds present in the environment.

When Does Exposure Happen?



You can reduce your exposure to organic chemicals in pesticides by wearing coveralls and gloves and following the procedures described for safe handling and use of the pesticide. Recall that the volatility and solubility of organic compounds results in their transfer into air and water.

All species are exposed to a variety of synthetic organic compounds in air, water, soil, and food. Many scientific studies have resulted from concerns about human health and focused on “how much” and “for how long.” Some studies have demonstrated a connection between high levels of exposure or prolonged exposure and certain diseases. To maintain good health, humans have a responsibility to make wise decisions about materials they use and their effect on themselves and on the environment.



You have learned the importance of organic compounds in society. The use of pesticides—whether used in agriculture, industry, or your home—indicates that they are an important class of synthetic organic compounds. As the “Alberta Pesticide Sales by Sector (1993–2003)” graph indicates, pesticide use in Alberta has changed very little over the ten-year period. The pattern of use and reliance on pesticides by society results in continual exposure to these compounds.

Tests on samples of drinking water in Alberta found trace levels of pesticides in more than 25% of the water supplied by water-treatment facilities. Recall that estrogen-mimicking compounds can also be present in other sources of drinking water. The presence of these compounds in water sources demonstrates the inability of water-treatment processes to remove them. Acceptable levels for organic compounds, including pesticides in drinking water, have been established, and routine testing of source water and drinking water is important to minimize exposure. Routine sampling and testing can also be used to identify sources of pollution.

Exposure can be the result of practices people follow. What do you do with the clothes you wear after handling pesticides? Is it possible to be exposed to substances used in your yard or garden when you are inside your home? Whether working on the golf course or at home, you need to be conscious of the safety instructions provided with each product. These instructions were developed in accordance with the properties of the particular organic compounds.

Simple actions—like washing your hands and clothes—in addition to following safety precautions reduce exposure.



DID YOU KNOW?

Some pesticides and other organic compounds can be present on the foods you eat. Washing fruits and vegetables with water containing a mild detergent before use can help remove residues from some products.



Practice

35. Refer to the “Alberta Pesticides Sales by Sector (1993–2003)” graph on page 292.
- Determine the mass of active ingredient of pesticides used by agriculture and domestic users in 2003.
 - Calculate the factor difference between the mass used by agriculture as compared to the mass for domestic use.
 - Comment on the labelling of the vertical axis for this graph.

Reducing Exposure—Actions Making a Difference



DID YOU KNOW?

Skin rashes can be a result of exposure to pesticides. Pesticides absorbed into the fabric of hats, coveralls, and other clothes concentrate over time and become a source of exposure when worn again.



One change people can make to reduce exposure to pesticides is to carefully consider not only the choice of products available, but why a pesticide is being used, and whether it is controlling the pest population. This may require consulting experts at garden centres or other knowledgeable people. Selecting the right product not only results in efficiently controlling pests, but has additional benefits, like minimizing the amount used, thereby reducing your personal exposure.

In your garden and flower beds, you may choose to control pests using alternative strategies. Selecting plants that demonstrate resistance to pests or selecting plants that require less chemicals to support their growth are two such strategies. Alternatively, routinely caring for plants by removing weeds and insect eggs as they appear can directly control many pests and reduce the need to use pesticides.

Integrated pest management is a comprehensive approach to controlling pests that involves all available strategies including

- using natural predators, parasites, and biological agents for controlling target pests
- using crop varieties resistant to pests
- carefully managing habitat using strategies like flooding or burning to deter the growth of pests
- carefully monitoring crop condition and number of pests
- using pesticides only when necessary

Canola farmers in Alberta might be quite familiar with the bertha armyworm. The larva of this insect is responsible for damage to canola and other crops. Adapting an integrated pest-management strategy to control bertha armyworms involves the practices listed in the “Controlling Bertha Armyworms” table.



CONTROLLING BERTHA ARMYWORMS

Practice	Effect on Bertha Armyworm
tilling (ploughing fields after harvest) and removing stubble from fields	<ul style="list-style-type: none"> • prevents accumulation of snow • exposes insect eggs to lower temperatures during winter • decreases protection for newly hatched larva
biological control strategies (e.g., introducing viruses and other insects)	<ul style="list-style-type: none"> • reduces bertha armyworm population by causing disease (virus) or weakening the organism (parasitic wasps)
planting alternative crops	<ul style="list-style-type: none"> • reduces available food for armyworms, thus reducing their population
using selective pesticides (if needed)	<ul style="list-style-type: none"> • kills insect population

It should be noted that the information about controlling bertha armyworms encourages farmers to evaluate the extent of infestation of their crops and its economic effect before spraying. As you have been encouraged to do throughout this course, identifying risks and benefits from ecological, economic, as well as other perspectives is an important part of decision making.

Some strategies for pest reduction focus on the use of naturally occurring compounds. The toxin produced by the soil bacteria *Bacillus thuringiensis* (Bt) can kill certain insect species. Since the toxin is harmless to humans, spraying the toxin on infested crops provides temporary control of some pests. To permit pest control during the entire life of corn and some other crop plants, the gene responsible for toxin production was used to produce genetically modified varieties of crop plants. As you might expect, resistance to Bt toxin has already begun to develop in some species of insects.

Science Links

Crops that produce the Bt toxin are examples of transgenic organisms. A process used to move genes from one organism into another and how genetic resistance can develop is explained in Unit A.



Practice

36. Explain why observation is an important aspect of pest-control strategies.
37. Identify which strategies listed at the top of the page could act to reduce the use of synthetic organic compounds in pest management.
38. Briefly explain a process by which a resistant insect population to Bt toxin could develop.
39. Match the practices used to control bertha armyworms to the strategies identified as part of integrated pest management.

Proper disposal of unused products and their containers, regardless of the quantity, can prevent the transfer of pesticides and other organic compounds into the soil and water sources. Many cities have special waste-handling facilities that permit the separation of materials containing persistent organic substances, like paint and pesticides. Taking the time to identify and transport materials to a handling facility prevents toxic materials from ending up in your household garbage where it might negatively affect the environment.



Figure B2.28: A waste-handling facility in Edmonton

Practice

Some roads are designated routes for the transport of dangerous goods.



40. Identify a roadway in your local area that is designated as a dangerous goods route. Use a map or describe the location of this route within your local area. List the risks and benefits with the route chosen.

Try This Activity

Current Opinions on the Use of 2,4-D

Background Information

2,4-D was first introduced as a herbicide in 1944. Although a great deal of testing and scientific data exists about its properties and behaviour in the environment, controversy exists over its use. Recently, the use of 2,4-D was brought into question and investigated by federal, provincial, and municipal governments in Canada.



Science Skills

- ✓ Analyzing and Interpreting
- ✓ Communication and Teamwork

Problem

What is the current position of your local municipality regarding the use of herbicides containing 2,4-D? What scientific authority is used to support the decision regarding the level of use of 2,4-D by the municipality?

Procedure

Investigate the questions stated in the problem by accessing relevant and reliable sources of information that exist within and outside your community. Prepare a presentation that summarizes the results from your investigation and makes explicit reference to scientific data and the sources of information collected.



DID YOU KNOW?

Waste-handling facilities can accept containers of unidentified chemicals. Unknown and highly toxic materials may be transported to the Swan Hills Waste Treatment Centre for processing.



At the beginning of your study in this unit, you completed the “Detection Limits” activity. In this activity you considered how important it is to be able to detect chemicals present in the environment. Given what you have learned about the concerns regarding exposure to persistent organic compounds, the detection of chemical substances, even at low concentrations, is important for certain compounds.

Many environmental samples are analyzed using a gas chromatograph mass spectrometer (GCMS). In the next activity you will investigate how this device operates and how it is used by scientists studying the environmental impact of organic compounds.

Utilizing Technology

Detecting Organic Compounds Using a GCMS

Background Information

Throughout this unit, you have become aware that many of the substances in air, water, soil, and animal tissues may be present in very small concentrations. The gas chromatograph mass spectrometer (GCMS) is an important apparatus used in the study of environmental science. This device detects and identifies substances present in quantities as low as a picogram.

Purpose

You will analyze data collected using a GCMS and determine if bioremediation of a crude oil component has occurred.

Procedure

step 1: Obtain the handouts “GCMS—Diagram” and “GCMS—Data” from the Science 30 Textbook CD.

step 2: Use the Internet to find a diagram or animation of the parts of a GCMS and their functions.

step 3: Label the parts of the GCMS and their functions on your copy of the diagram.

step 4: View the applet “Using the GCMS and Bioremediation” from the Science 30 Textbook CD.

Analysis

1. Compare the mass of 1 pg (picogram) to 1 mg.
2. Use the diagram of the GCMS to identify where the separation of compounds occurs.
3. Explain how the GCMS provides information on the quantity of each compound in a sample.
4. Refer to the “GCMS—Data” handout. Did the bacterial culture in the flask affect the dibenzothiophene present in the sample? Explain how you used the GCMS spectra to support your answer.



Science Skills

✓ Analyzing and Interpreting



DID YOU KNOW?

The detection of caffeine in surface water samples is an indicator of pollution from human sewage. The water qualities of popular lakes are often monitored for caffeine and other indicators of pollution from human sources.

POPs in the Arctic

In this chapter you learned about mechanisms like the grasshopper effect and the polar vortex that have drawn molecules identified as persistent organic pollutants (POPs) toward the Arctic. Given the climate, the potential for the breakdown of these molecules by bioremediation is very low. Scientists examining the tissues of organisms in arctic food chains have identified bioaccumulation of persistent compounds. In addition to the work done by scientists, observations made by the Inuit, including changes to the numbers of offspring and breeding behaviours of animals, suggest that something present in the environment might be having an effect. The contributions of the traditional ecological knowledge of the Inuit and the data collected by scientists may provide an opportunity for a deeper understanding of the changes occurring.

Utilizing Technology

Investigating the Effects of POPs in the Arctic

Background Information

Observing how the issue of climate change is being addressed by the Inuit community and scientists provides an opportunity to determine how other environmental issues could be studied in a way that involves the communities affected. At the end of this activity, you should be able to

- describe information that could be classified as traditional ecological knowledge
- explain how the consideration of traditional ecological knowledge could contribute to greater scientific understanding

Purpose

You will write a research proposal that describes how you would investigate the impact of persistent organic pollutants in the arctic ecosystem.

Preparation

You may find that as you watch the video, important information appears quickly. Before you watch the video, think of strategies you may need to use so you can identify, extract, and, if necessary, go back and find important information. Before you view the video, read the Analysis questions. Prepare a table to record information as you view the video.

Procedure

View the video “Sila Alangotok—Inuit Observations on Climate Change” from the Science 30 Textbook CD. View the video once in its entirety; then, review specific sections as needed. Use the information from the video to answer the Analysis questions.



Analysis

1. Prepare a list of several changes to the environment that have been observed by the residents of Banks Island.
2. What research question were the scientists investigating?
3. Why did the scientists ask the people of Banks Island to describe their observations?
4. Using examples, describe how the observations of the residents of Banks Island demonstrate a holistic view of ecosystems.
5. Are the residents of Banks Island asked to express opinions or describe observations? Support your answer.



Science Skills

- ✓ Initiating and Planning
- ✓ Analyzing and Interpreting
- ✓ Communication and Teamwork

6. Do you feel the contribution of the residents of Banks Island is being respected? Support your answer.
7. Review the parts of a scientific study.

Parts of a Scientific Study

- (1) collection of background information
- (2) development of a hypothesis
- (3) development of a problem statement
- (4) development of a design for experimental work
- (5) collection of data
- (6) analysis of data
- (7) interpretation of data
- (8) sharing of conclusions

Identify the parts of a scientific study where the contribution of traditional ecological knowledge may benefit the scientific process. Provide support for your answers.

8. How does the oral tradition of First Nations impact the ability to access traditional ecological knowledge?
9. Describe possible benefits that could come from consulting Aboriginal populations in this study or in other studies.
10. Describe possible risks that could come from consulting Aboriginal populations in this study or in other studies.
11. Identify the main concern about climate change expressed by the residents of Banks Island.

Communication and Teamwork

12. Write a research proposal that describes how you would investigate the impact of persistent organic compounds in the arctic ecosystem. In your proposal, accurately define what you wish to study and how you intend to study it. List and justify the experiments and other investigations you intend to carry out. Indicate the equipment necessary for your study and explain why it must be used. If possible, justify the use of traditional ecological knowledge by describing how you will collect this type of data and why this type of information would be useful to the goals of your study.

The Dirty Dozen

The “dirty dozen” are twelve persistent organic pollutants (POPs) that were identified by the Stockholm Convention—the first international agreement on POPs held in 2001. Due to the polar vortex, many of the substances in the “dirty dozen” have migrated from lower latitudes to the Arctic and have been detected within arctic food chains.

THE DIRTY DOZEN

Chemical Substance	Purpose
Aldrin	pesticide
Endrin	pesticide
Dieldrin	pesticide
hexachlorobenzene (HCH)	pesticide
Chlordane	pesticide
Heptachlor	pesticide
Mirex	pesticide
Toxaphene	pesticide
DDT	pesticide
PCBs	industrial processes
Dioxins	industrial processes
Furans	industrial processes

2.3 Summary

Exposure to low concentrations of synthetic organic compounds present in the environment may be long term or short term. Pesticides and building materials are two of the many possible examples of how these organic compounds are used. Some persistent organic compounds include halogenated hydrocarbons. Biomagnification of persistent compounds in ecosystems is an environmental problem in many ecosystems, including the Arctic. Assessing the need to use synthetic chemical technologies and finding alternatives are important steps to reducing negative effects from exposure to these compounds.

2.3 Questions

Knowledge

1. State one type of substance released during off-gassing.
2. Define *toxicity*.
3. Describe a benefit of having data from LD₅₀ or LC₅₀ tests.
4. List a source and two health effects that result from exposure to dioxins.
5. Identify the group of organic molecules to which dioxins and furans belong.

Applying Concepts

6. Explain the rationale for testing the LD₅₀ for a pesticide in many organisms that form a food chain within an ecosystem.
7. Write the chemical structures that correspond to the red, blue, and green parts of the systematic name for the herbicide 2,4-D.

2,4-dichlorophenoxyethanoic acid

8. Predict the effect the following weather conditions would have on the concentration of a pesticide in air, surface water, and soil in the area in which it is sprayed.
 - a. a rain shower that occurs within an hour after spraying the pesticide
 - b. spraying occurs on a hot day
9. Explain, in terms of reducing personal exposure to pesticides, why it is important to consult with local experts before use and to observe the effect of a pesticide after its use.
10. Review the principles of organic farming practices.

Principles of Organic Farming Practice

- Protect the environment, minimize soil degradation and erosion, decrease pollution, optimize biological productivity, and promote a sound state of health.
- Maintain long-term soil fertility by optimizing conditions for biological activity within the soil.
- Maintain biological diversity within the system.
- Provide attentive care that promotes the health and meets the behavioural needs of livestock.
- Prepare organic products, emphasizing careful processing and handling methods in order to maintain the organic integrity and vital qualities of the products at all stages of production.

Identify how the use of synthetic compounds as pesticides or as fertilizers is not consistent with the practices listed.

11. Explain a situation in which you would choose to use chemical pesticides as part of an integrated pest-management strategy.
12. Describe how the development of a Bt genetically modified crop plant may lead to the development of insect populations resistant to the Bt toxin.



Chapter 2 Summary

In this chapter you studied different classes of organic compounds, including their use and impact on the environment. You identified and named halogenated hydrocarbons, alcohols, carboxylic acids, and ester compounds. You also examined the structure and properties of benzene rings and the importance of aromatic and polycyclic aromatic compounds.

Organic molecules were developed for many purposes. Throughout the chapter you were introduced to the uses of different types of organic molecules and, in some cases, their unexpected effects. Some by-products of organic reactions, including dioxins and furans, are examples of harmful persistent organic compounds that can cause mutations and even cancer.

Exposure to pesticides and other substances can have negative health effects; but actions taken by individuals and by society can reduce the presence of these substances in the environment. You also examined techniques for conducting studies and you became aware of the importance that detecting organic compounds in the environment has in studying their effects.

Summarize Your Learning

In this chapter you covered a number of chemical terms, types of organic compounds, chemical reactions, and a great deal about the impact that the development and use of chemical compounds has had on the environment. You may have collected news articles about chemical issues and the environment. You will have a much easier time recalling the application of the information you learned if you take some time to organize it into a pattern. Now that you have come to the end of this chapter, this is an appropriate time to focus on the patterns in the things you have learned.

Since the pattern has to be in a meaningful form to you, there are some options about how you can create this summary. Each of the following options is described in “Summarize Your Learning Activities” in the Reference Section.

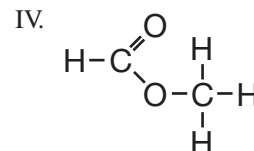
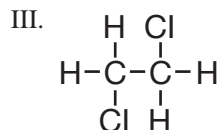
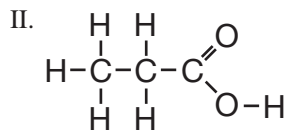
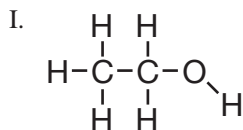
Option 1: Draw a concept map or a web diagram.	Option 2: Create a point-form summary.	Option 3: Write a story using key terms and concepts.	Option 4: Create a colourful poster.	Option 5: Build a model.	Option 6: Write a script for a skit (a mock news report).
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Chapter 2 Review Questions

Knowledge

- State the suffix used when naming organic compounds with each of the following functional groups: hydroxyl, carboxyl, and ester.
- State the reactants necessary to synthesize an ester.
- Match each name with the chemical structures given.

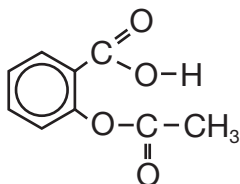


- 1,2-dichloroethane
 - methyl methanoate
 - ethanol
 - propanoic acid
- Use the list of chemical structures to identify parts of each molecule given. **Hint:** More than one structure may be identified in each molecule.

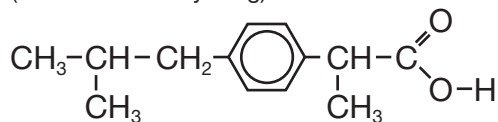
Chemical Structures

- benzene ring
- hydroxyl functional group
- carboxyl functional group
- ester functional group
- halogen atom

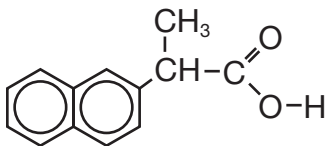
- Acetylsalicylic Acid (ASA)**
(anti-inflammatory drug)



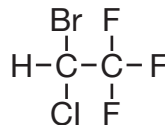
- Ibuprofen**
(anti-inflammatory drug)



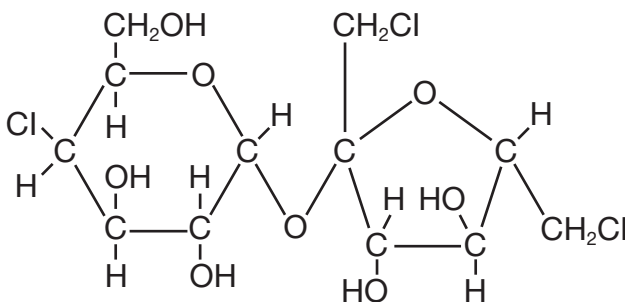
- Naproxen**
(anti-inflammatory drug)



- Halothane**
(anaesthetic gas)



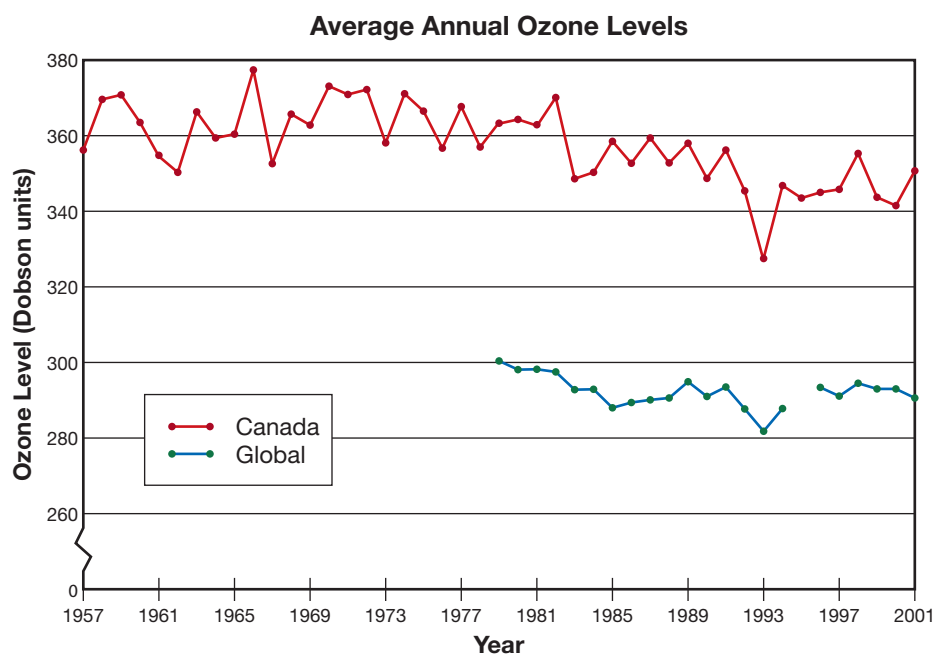
- Sucralose**
(artificial sweetener)



5. State a technology or application for each type of organic compound given.
 - a. halogenated hydrocarbon
 - b. alcohol
 - c. carboxylic acid
 - d. ester
6. Define *persistence*. State two examples of organic compounds considered to be persistent substances.

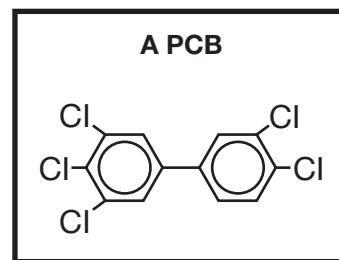
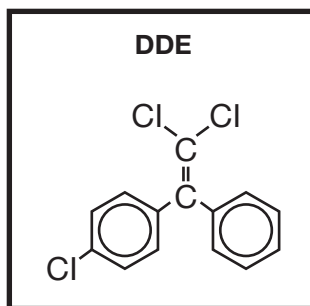
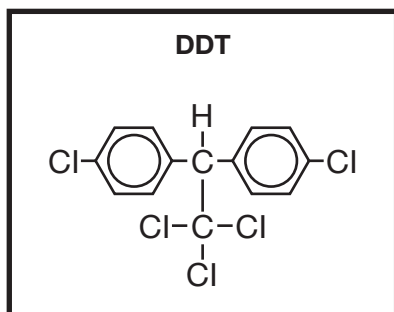
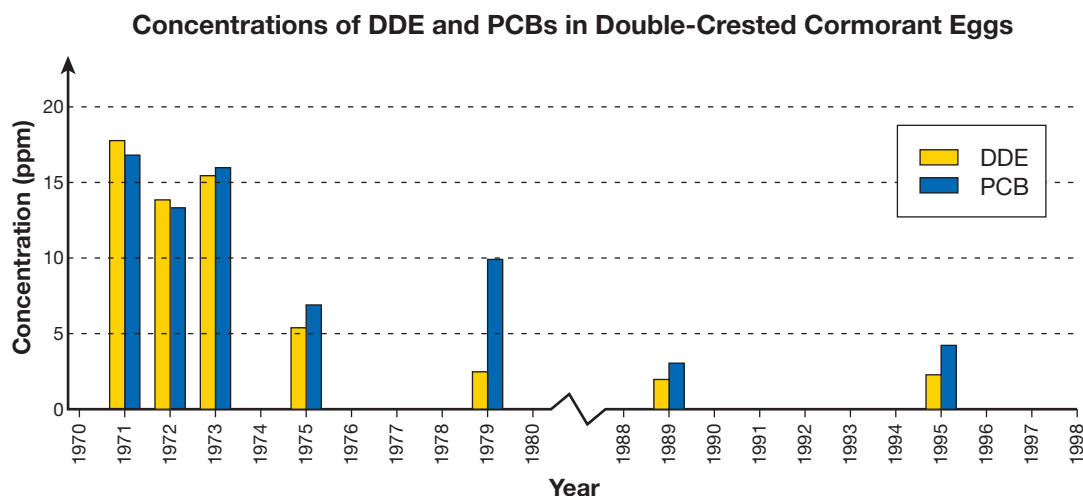
Applying Concepts

7. List similarities and differences between the hydroxyl, carboxylic acid, and ester functional groups.
8. Describe the effect that the leaching of fertilizers used in agriculture can have on a body of water.
9. List some products that contain volatile organic compounds (VOCs). Explain how exposures to VOCs occur in outdoor and indoor settings. State health risks associated with VOCs.
10. Explain how bioremediation can be used to remove organic compounds from soil and water.
11. List some water-borne diseases. Describe processes that can reduce the incidence of water-borne diseases.
12. Define *BOD*. What does a water sample with a high BOD indicate? Explain why surface water with a high BOD is undesirable.
13. Why do chlorinated hydrocarbons remain in the soil and water for such a long time?
14. List the advantages and disadvantages of using chemical pesticides.
15. Use the following graph to answer questions 15.a. to 15.d.



- a. Determine the year in which the largest drop in stratospheric ozone occurs.
- b. Explain why stratospheric ozone concentration is not expected to increase in the near future.
- c. List the consequences of ozone depletion.
- d. Identify regions of Earth where ozone depletion is greatest. Explain why some regions of Earth experience greater ozone depletion than others.

16. A long-term study investigating synthetic organic compounds in the environment was conducted using the eggs of cormorants, a fish-eating bird, in an area surrounding a major lake. The concentration of DDE (the main breakdown product of the pesticide DDT) and PCBs are shown in the following graph.



- Identify parts of the chemical structure of DDT and PCBs that suggest that these compounds might be persistent in the environment.
- DDE present in organisms comes from the body's action to absorb DDT. DDE has been shown to have toxic effects on the immune and nervous systems and the thickness of eggshells in birds. Evaluate this information, and justify whether it is appropriate to show DDE concentrations on the graph and to use these levels to make conclusions about the presence of DDT in the environment.
- Explain how the data shown in the graph demonstrate that DDT—an insecticide banned in Canada since 1974—and PCBs—industrial chemicals that have been highly restricted since 1977—are persistent organic compounds.
- Describe sources of persistent organic pollutants in the environment.